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Procedia Materials Science 5 (2014) 1114 – 1119

Procedia Materials Science

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International Conference on Advances in Manufacturing and Materials Engineering, AMME 2014

Strength Degradation of Mechanical Properties of Unidirectional E-Glass Fiber Epoxy Resin Nanoclay Composites under Hygrothermal Loading Conditions

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Abstract

Glass fiber reinforced polymer (GFRP) plays a vital role in many industries because of its high strength to weight ratio. Its strength properties are somewhat lower than carbon fibre and it is less stiff and brittle. Using glass fibre in industries because of its raw material is much less expensive with compare to other materials. In the present work, the epoxy resin was modified using natural montmorillonite Closite 30B (1 wt%, 3 wt%, 5 wt%) nanoclay is used with E-glass unidirectional fiber to manufacture fiber reinforced nanocomposite using hand layup method. Three different types of fiber reinforced nanocomposites are fabricated using 1wt% nanoclay, 3wt% nanoclay and 5wt% nanoclay with 30% wt fiber, epoxy resin and hardener. The epoxy resin and hardener are mixed in 10:4 weight ratios. Three different test, tensile test, hardness test and flexural test were measured through using mechanical test instruments. The mechanical test shows that the tensile and flexural strength for 3wt% nanoclay composite is more compared to 1wt% and 5wt% nanoclay composite. To improve the flexural and tensile properties are 57% and 8% respectively by adding 3wt% of nanoclay. Micro hardness test for 3wt% of nanoclay composite is higher compare to 1wt% and 5wt% nanoclay composite and further increase beyond 3wt% nanoclay hardness start decreasing .Further check durability the specimen were immersed in water and NaOH baths under accelerated hygrothermal loading for 30 days. Due to accelerated hygrothermal loading it is observed that the mechanical properties degradation in NaOH environment was more severe as compared to simple water.

Selection and peer-review under responsibility of Organizing Committee of AMME 2014

Keywords: Unidirectional E-Glass Fiber; Epoxy Resin; Nanoclay; Hardener.

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Selection and peer-review under responsibility of Organizing Committee of AMME 2014
doi:10.1016/j.mspro.2014.07.405

1. Introduction

Fiber reinforced polymer (FRP) is one of the fastest growing classes of the thermosetplastics. The growth of glass fiber is attributed to its low cost, low density, and high heat distortion temperature. These materials have become the alternative of conventional structural materials such as steel, wood or metals in many applications. The application of glass fiber reinforced polymer composites are car industry, marine industries, aircraft fabrication, wind power plant, etc. We are entering in to the gateway of next generation "nanotechange", where smaller and shorter things will play a big role. Nanotechnology will find its application in energy, medicine, electronics, computing, security and materialsciences, etc. Nanoclay is the most commonly used tool for the preparation of nanocomposites. The nanoclay is use of smectite family and groups of saponite, hectorite, and Montmorillonite are the most commonly used montmorillonite layered silicates. Layered silicate nanofillers have proved to trigger a tremendous property. Improvement of the polymers in which they are dispersed by using motor sirrer and then ultrasonication for giving sound energy to the epoxy matrix. Those mechanical properties, a large increase in tensile and flexural strength of nanocomposites at filler contents sometimes as low as 1 wt% has drawn a lot of attention. The new materials have also been studied and its apply for their superior barrier properties against gas and vapour transmission. The composite material depending on the type of polymeric matrix, they can also display interesting properties in the frame of ionic conductivity or thermal expansion control. Addition of very less amounts of nanoclay into epoxy matrix for improving the moisture barrier properties, tensile strength and flexural strength, hardness, toughness and impact properties. For manufacturing fiber reinforced polymer nanocomposites, the dispersion of nanoclay into epoxy resin using motor stirring and then give the sound energy by ultrasonication. The organically modified polymer matrix is then reinforced with fibers to manufacture fiber nanoclay hybrid composites using conventional composite manufacturing methods. To improving mechanical properties of polymer using various kinds of fillers. It is now well recognized that the use of inorganic fillers is a useful tool for improving mechanical properties of polymer by Davallo et al. (2010). The polymer nano composites (PNC) are now prepared by different methods namely Brabender mixer and Hand mixing. PNCs are also made using a large variety of thermoplastic polymers. Though fiber reinforced nanocomposites have been investigated by many researchers, a comprehensive study on effect of nanoclay addition on mechanical properties of fiber reinforced/nanoclay hybrid composites subjected to hygrothermal conditions has not been performed so far. The present work is thus focused on investigating the effect of nanoclay addition in different proportions on mechanical properties of fiber reinforced epoxy composites and degradation in mechanical properties of fiber/nanoclay-epoxy hybrid nanocomposites under hygrothermal conditions by Selvakumar et al. (2010).

2. Experimental Procedure

Unidirectional E-glass fiber and M Brace a two part epoxy resin purchased from Nav Bharat Agencies, Jalandhar (Punjab). Natural Montmorillonite Modified Closite 30B purchased from Intelligent Materials Pvt. Ltd. The density of the mat is 900g/m^2. The fibre content in the three composites are 30 wt% of total weight of the composite. The epoxy resin used for this investigation is Diglycidl Ether of Bisphenol A (DGEBA) and Hardener (polyamine). They are mixed in 10:4 weight ratios. The epoxies in the three composites are 69wt%, 67wt% and 65wt% of total weight of the composite. Nano clay was added to epoxy resin in different weight percentage of resin: 1%, 3%, and 5%. The modified epoxy was then reinforced with glass fibres to manufacture Fibre reinforced polymer nanocomposites.

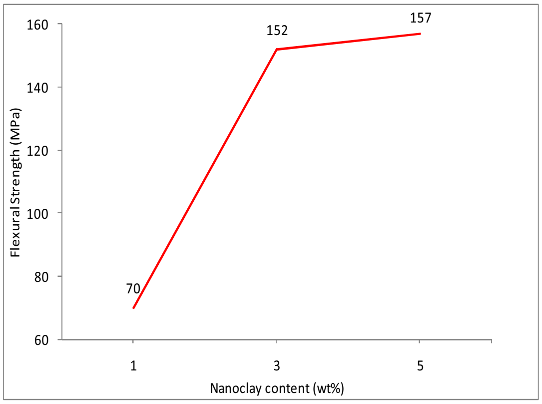
3. Composites Preparation

The composite material used for this study is prepared by hand layup method in Fig. 1. The epoxy resin was continuously through motor stirrer and heated in an oil bath for 2 h, maintained constant temperature 60 ^{0}C of oil bath through voltage regulator. Nanoclay in different proportions was added slowly to resin and then stirring was done for 2 h. After mechanical stirring, modified epoxy solution container was placed in to the ultrasonication bath for give the sound energy. Sonication can be used to disperse nanoparticles in liquids by breaking intermolecular interactions. After mechanical stirring of the epoxy solution container was placed into the ultrasonication bath for up to 2 hours. After sonication the solution was mixed with the hardener and stirring up to 10 to 25 min was done. After this the mixture was applied to fibre sheet on one sides using hand layup and left 18 h for drying and then again after 18 h the mixture was applied on another side. The laminas were cured by leaving them under ambient temperature for seven days. And after seven days the composite material will ready for testing mechanical properties.

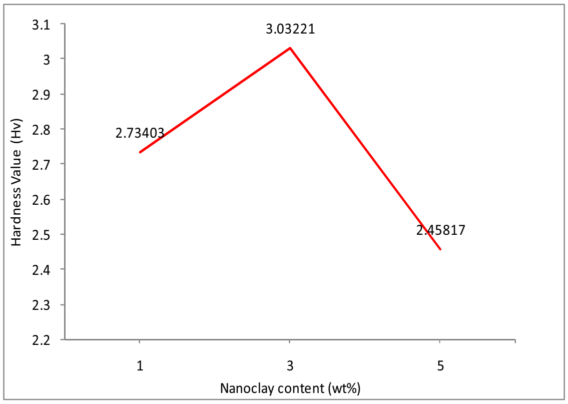
Fig. 1. Hand Lay Up Method

4. Results and Discussion

Three point bending test results perform on FRP specimens are shown in Figure 2a.it indicates that the flexural strength increases from the 1wt% nanoclay composite to 3wt% nanoclay composite and then decreases with further addition of nanoclay. The flexural strength of 3wt% nanoclay composite is the maximum among the three composites. For finding change in hardness values, measurements were taken at 5 points on each specimen from the results of hardness test it is observed that the hardness increases with increase in % nanoclay. However, further increase in % wt nanoclay hardness starts decreasing. The maximum hardness was observed for 3wt% nanoclay composite. The results are shown in Figure 2b.



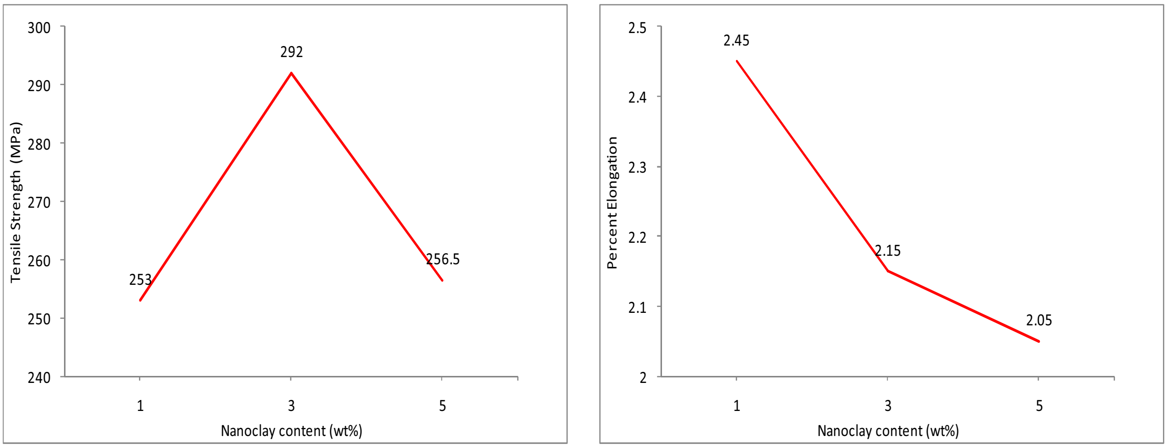
(a)



(b)

Fig. 2. (a) Flexural strength of FRP nanocomposites and; (b) Hardness values

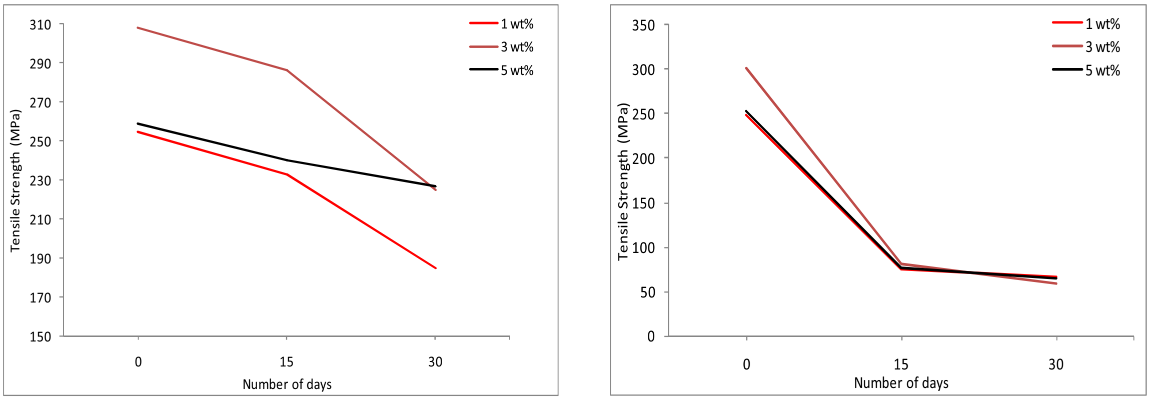
Tensile tests were carried out on a minimum of three specimens containing same amount of clay according to ASTM-D-3039 using Zwick-Roell universal testing machine. With the addition of nanoclay the value of tensile strength increased for clay loading up to 3 wt% and then it decreased Figure 3a. A decrease in percent elongation was found with the increase in clay content, which indicates that, the brittleness of matrix increased with increase in clay loading.



(a) (b)

Fig. 3. (a) Tensile strength (MPa) of FRP nanocomposites at different clay loadings; (b) percentage elongation

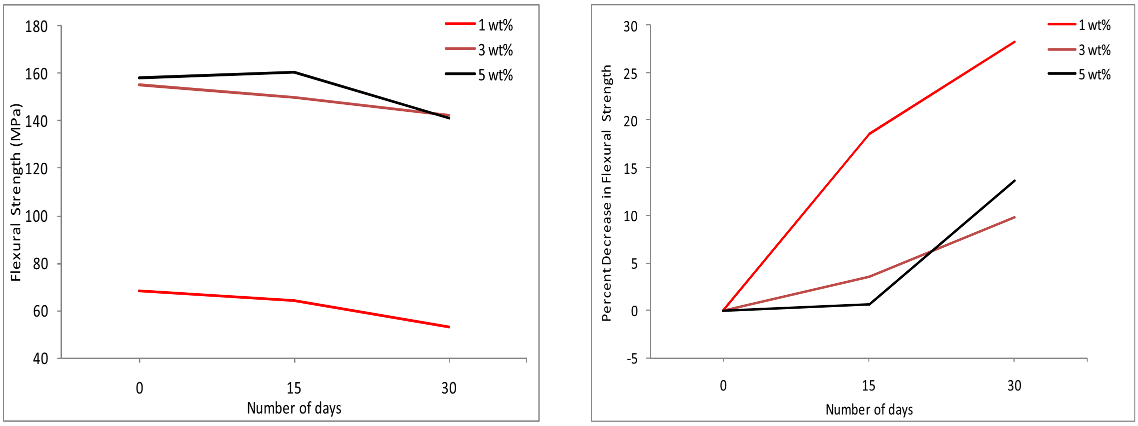
For carrying out the durability studies specimen were dipped in a water bath maintained at 45 ^{0}C and a NaOH solution bath maintained at 45 ^{0}C for a period of one month. The liquid which evaporated from the tank was replenished on daily basis during experimentation. Before testing, the specimens were taken out and dried with the help of cloth and kept in ambient environment. The tensile strength and flexural strength measurements were taken to understand the effect of high temperature and moist conditions on these properties.



(a) (b)

Fig. 4. Tensile Strength degradation versus time (a) in water bath; (b) in NaOH bath

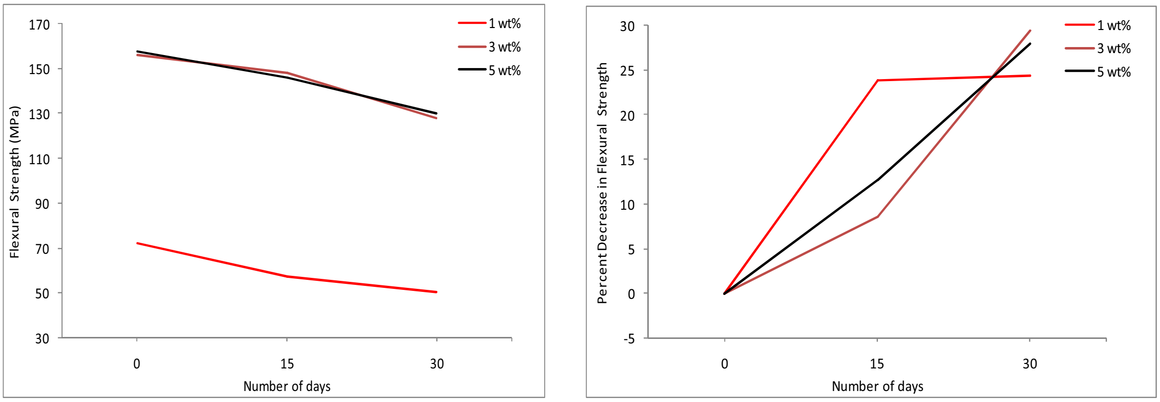
Figure 4 shows the effect of clay loading on tensile strength of samples immersed in water bath and NaOH bath. The tensile strength of all specimens decreased with time but in samples containing clay, the decrease was less in comparison to specimens without nanoclay. It can be seen that in specimen with 3 wt% nanoclay the degradation was least as compared to other specimens. It is observed that in specimen immersed in water, the strength degradation is more severe during a time period of 15 to 30 days, whereas in samples immersed in NaOH bath, the degradation was more in first 15 days.



(a) (b)

Fig. 5. (a) Flexural Strength degradation; and (b) percent decrease in strength in water bath

Figure 5 shows the effect of immersion of specimen in water on flexural strength of specimen. It can be seen from Figures 5a and b that 3 wt% nanoclay specimen outperformed in terms that the degradation in flexural strength in water bath was less in comparison to other specimens.



(a) (b)

Fig. 6. (a) Flexural Strength degradation; and (b) percent decrease in strength in in NaOH bath

However in NaOH bath, as can be seen from Figures 6a and b, the strength degradation was approximately same for 3 wt% and 5 wt% specimens. The neat epoxy – fiber composite suffered a steep drop in strength in both water and NaOH bath.

5. Conclusion

Fiber reinforced nanocomposites have been manufactured using glass fiber as reinforcement and epoxy mixed with Closite 30 B as matrix. Nanoclay was added to epoxy in different weight percentage (1 wt%, 3 wt% and 5 wt%

of weight of resin). For the processing of epoxy-nanoclay mechanical stirring and ultrasonication was done. Better intercalation of clay in epoxy was observed in samples with 1 and 3 wt% clay loadings. Clay agglomerates were found in 5 wt% samples. Tensile and bending tests were performed on nanocomposites as per ASTM standards. It was found that the hardness of the nanocomposites increased with increasing nanoclay content. However, it was also seen that there was an optimal limit. Tensile strength and flexural strength of the 3 wt% and 5 wt% clay content samples were improved. The durability studies were conducted on nanocomposites by exposing to water and alkaline medium for a period of one month then evaluating the mechanical property degradations. Mechanical properties were found to degrade with increase in time. 3 wt% GFRP composites showed less degradation and better properties under all conditions over neat counterparts. The water resistance property of epoxy was improved by the addition of both glass fibre and nanoclay, which is maybe attributed to the increasing of the tortuosity path for water penetration.

Acknowledgement

Sanjeev Kumar Singh is thankful to National Institute of Technology, Kurukshetra, Haryana, India-136119, for the financial support in the form of Scholarship.

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